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Plant Community Structure from the Jilmoi Wetlands to the Donghae Observatory, Baekdudaegan Mountains[1]

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ABSTRACT

This study aims to investigate the characteristics of the vegetation structure in the sectin stretching between the Jilmoi wetlands and the Donghae Observatory and to set the criteria for the basic data for a management plan including restoration afterwards. 12 plots(10 m×40 m, 20 m×20 m) were set up to analyse the vegetation structure.

The analysis of the classification by TWINSPAN and ordination by DCA, importance percentage and property, distribution of diameter of breast height, growth increments of major woody species, species diversity and the physicochemical properties of soil were all analyzed.

Vegetation classes were divided into 3 communities, which are community Ⅰ(*Pinus densiflora* community), community Ⅱ(*Quercus mongolica* community) and community Ⅲ(*Quercus mongolica-Tilia amurensis* community). The *P. densiflora* community declined when competing with *Q. mongolica* and *Fraxinus rhynchophylla* and *Q. mongolica* competed with *T. amurensis* on an understory layer in *Q. mongolica* community. *Q. mongolica* competed with *T. amurensis* on both canopy and understory layers in *Q. mongolica*-*T. amurensis* community. *P. densiflora* declined and it was assumed to succeed to *F. rhynchophylla* or *T. amurensis* through *Q. mongolica* based on the importance percentage and distribution of the diameter of the breast height of small and middle sized trees. The age of *P. densiflora* was between 47 to 51 years old and *Q. mongolica* was 61years old. *T. amurensis* was 61 years old and the growth of *Q. mongolica* slowed a little. As the result of Shannon's index of species diversity, community Ⅰ ranged from 0.9578 to 1.1862, community Ⅱ ranged from 0.7904 to 1.2286 and community Ⅲ ranged from 0.8701 to 1.0323. The contents of organic matter and cation were low compared to uncultivated mountain soil and it were analysed to be inappropriate for tree growth.

KEY WORDS: ALTITUDE, VEGETATION STRUCTURE, SUCCESSIONAL TREND , Quercus mongolica COMMUNITY

INTRODUCTION

The Baekdudaegan Mountain Range begins at Mt. Baekdusan and extends to Wonsan, Geumgangsan, Odaesan, Soknisan and Deokyusan Mountains all the way to Mt. Jirisan, making it Korea's longest mountain range. The concept of 'Baekdudegan', which means a mountain range that stretches out of Baekdusan, is a concept that is along the lines of feng shui and has been formed from the Goryeo Dynasty. However, only the Joseon Dynasty has the concept of mountain ranges and riversides which

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became common from the aspect of everyday living. A system of mountain maps was established after the mid 18th century in the late Joseon Dynasty (Yang, 1997).

The section between the Jilmoi Wetlands through the Donghae Observatory in Baekdudaegan is a key ecosystem axis located within the Odaesan National Park, which was designated as a national park in 1975. The nearby Jilmoi Wetlands are an international conservation area designated as a Ramsar site together with the Sohwangbyeongsan Wetlands and the Jogaedong Wetlands. Furthermore, the Daegwallyeong Samyang Pasture, which is Korea's only general organic livestock ranch, is spread wide and is located near the Marugeum of Baekdudaegan, and therefore has continuously received human interference.

The importance of managing Baekdudaegan, which is a key ecological axis as Korea's largest mountain range, began in the late 1990s when thoughtless development, such as the construction of large roads, was well underway. By sector, research has been continuously conducted regarding setting the management range, studies on the vegetation structure characters by the Marugeum sections in Baekdudaegan, plans to restore damaged areas, and an environmental analysis of Baekdudaegan. In particular, many studies were conducted regarding the vegetation structure features per section due to the characteristics of the vast 670km section.

When examining preceding studies related to Baekdudaegan for setting the management range Yoo (2002) conducted a study to establish a conceptual management range model of Baekdudaegan, and assessed the ecological, physical and socio-cultural indices to divide the area into three zones a preservation zone, buffer zone, and multi-use zone. Kwon *et al.* (2004) attempted to set the efficient management range of Baekdudaegan through GIS hydrographic analysis and used the watershed expanding method to analyze changes in land usage depending on the watershed degree, and in result set the 5th-8th degree watershed areas as the management range. Shin (2004) claimed that in border setting for appropriate space, it must be set based on traditional thinking and that the management range should be set considering the natural environment. Shin set the management range up to the third degree water system and claimed that the conservation area must include at least one water system.

In the Baekdudaegan Marugeum vegetation study, there are many studies on investigating the flora and plant community structure by sector. In studies on plant species, research on the status of the plant species distribution by section (Kim *et al.*, 2003; Lim, 2003) and species appearance features by topography (Choung, 1998) have been conducted. In the plant community structure studies where research is most active, while focusing on studies on plant community structure distribution features by sectors (Choo and Kim, 2004; Cho *et al.*, 2005; Choi *et al.* 2004; Kim and Choo, 2003; Lee *et al.*, 2012), studies on vegetation distribution features according to topographic changes in altitude and slopes (Choi *et al.*, 2003; Hwang *et al.*, 2012; Park and Choi, 2004; Jeong and Oh, 2013) have been carried out. A considerable amount of features and succession tendencies per sector were investigated through preceding studies, and the decline of *P. densiflora* forests and succession to *Q. mongolica* forests, as well as the tendency of *Q. mongolica* forests to succeed to marsh deciduous broad-leaved trees or old stands (Kim *et al.*, 2003; Kim and Baek, 1997; Hwnag *et al.*, 2012).

In damaged area restoration plan research, there were studies on restoring the road slope for the case of Jirisan National Park (Seo *et al.*, 1991) and vegetation restoration (Oh *et al.*, 1998), and vegetation restoration plans for the forest fire area around Samshinbong (Lee *et al.*, 2001). From the aspect of damaged area management and restoration, they are all on Baekdudaegan Marugeum's highland farms, ranches and road slope faces, and it was mentioned that due to the planting of exotic species during the vegetation restoration of these areas, there were problems in terms of natural scenery and nature preservation. Recently, there was also a study on environmental assessments to strengthen management for areas with various land usage and that rated the ecosystem around Baekdudaegan Marugeum (Lee and Lee, 2013).

In the above studies, various research was conducted that proposed restoration plans for damaged areas and to set the management range focusing on studies on plant community features by sections. However, there are many areas that have not been investigated due to the vast range of Baekdudaegan, and it is necessary to establish a concrete management area setting and management plans for sections that requires the harmony of conservation and use.

Therefore, this study aimed at revealing plant community features and the succession trends for the section between the Jilmoi Wetlands through the Donghae Observatory, which was not yet examined in the past, and to ultimately be used as a form of basic data for conservation and management and to establish an ecological management plan for the Daegwallyeong Samyang Ranch that has been managed as an artificial ranch for a long period of time.

MATERIALS AND METHODS

1. Research Target Area

Odaesan National park was designated as the 11th national park of Korea in 1975 and covers a total area of 326 ㎢. It has a northern temperate climate and its warmth index stands at 65.6(℃·month, as of 2012). The target area of this study is the area near Daegwallyeong Samyan Pasture on the eastern side of Mt. Odaesan and is the approximately 5.7 ㎞ section from the Jilmoi Wetlands to the Donghae Observatory. And an altitude distributed between 1,052 m and 1,138m (Figure 1). The investigation area was selected along the Baekdudaegan ridge and takes into consideration vegetation changes where 12 investigation plots (10 m×40 m, 20 m×20 m) were set.

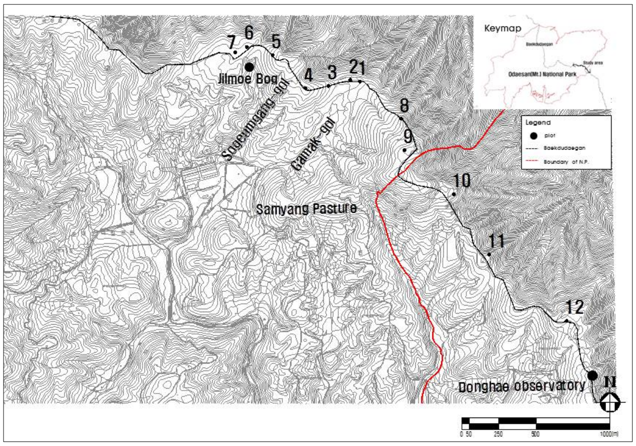

Figure 1. Location of the Study Area

2. Vegetation Structure and the Soil's Physical and Chemical Feature Examination Analysis

1) Vegetation Structure

The vegetation structure investigation was referred to in the method of Monk *et al.* (1969) and investigated the breast height diameter, tree height, timber height, and crown width for trees with a breast height diameter of more than 2cm for trees and understory, and the tree height, timber height, and crown width for trees with a breast height diameter of less than 2cm or a tree height of less than 2m for shrubs.

In order to compare the relative dominance of tree species based on vegetation investigation, the relative importance percentage (I.P.) (Brower and Zar, 1977) that was integrated and showed in percentage the importance value (I.V.) of Curtis and McIntosh (1951) was used to analyze by tree crown layer. I.P was calculated by (relative density + relative coverage)/2, and tree crown coverage was based on the breast height area. The mean importance percentage (M.I.P.) that granted weight value by tree crown layer considering the size of individual trees was found by {(3×tree I.P.)+(2×understory I.P.)+(1×shrub I.P.)}/6 (Yim *et al.*, 1980; Park *et al.*, 1987). As an indirect expression of tree age and stand movements, the distribution by the breast height diameter class (Harcomb and Marks, 1978) that can estimate the forest succession mode was analyzed. The sample trees were selected considering average dimensions among dominant species per inspection plot, and an increment borer was used 1.2m above the ground to extract a block of wood. In order to analyze the diversity of species by community, the number of species, number of individuals, Shannon's species diversity index (H') (Pielou, 1975), evenness (J'), dominance value (D), and max species diversity (H'max) were analyzed. Community classification used ordination analysis according to DCA (Hill, 1979a) and classification analysis according to TWINSPAN (Hill, 1979b), and by layer, and was classified by taking into consideration the species composition according to I.P. by layer.

2) Physical and Chemical Features of Soil

The soil physical and chemical features analyzed physical features such as soil and chemical features such as pH, organic material content (O.M.) available phosphate (Avail. -P), and exchangeable cation. Soil acidity analysis was carried out using the glass electrode method (1:1), and after agitation for one hour, it was measured repeatedly three times using a pH meter (TOA HM30V). The avail. -P was quantified according to the Bray No. 1 method

(Bray and Kurtz, 1945) and among exchangeable cation, Ca^{2+}, Mg^{2+} was quantified using the EDTA method and K^{+} using an atomic absorption spectrometry (SP-9, UNCAM Co., U.K.).

RESULTS AND DISCUSSION

1. Vegetation Structure

1) Classification and Ordination Analysis of Investigation Plot

Classification analysis was carried out based on TWINSPAN for 12 investigation plots. In level 1, division 1, it was divided into two groups depending on the appearance of Sorbus commixta (-), and in level 2, division, it was separated into two groups depending on the appearance of *F. rhynchophylla* (+). Based on the classification analysis results through TWINSPAN, it was divided into a total of three communities. Community I included investigation plots 8 and 11 (2 plots), Community II included investigation plots 1, 2, 3, 4, 5, 6 (6 plots), and Community III included investigation plots 7, 9, 10, 12 (4 plots) (Figure 2). Upon community classification, Community I showed *Q. mongolica* as the dominant species with differences among accessory species and Community II had a dominant species of *Q. mongolica* and *P. densiflora*. For Community Ⅲ, *Q. mongolic*a and *T. amurensis* were the dominant species with different accessory species.

Among the ordination methods analyzed using classification and mutually supplementing methods, the DCA techniques were used to analyze all investigation plots. The results showed inconsistencies in communities I, II and III, and was different with the classification of TWINSPAN. In plots 3, 4 and 6 where *P. densiflora* was the dominant species, they were distributed continuously on the right (Figure 3). Due to the character of target areas with similar topographies and relatively complex species composition of communities, it was difficult to distinguish communities clearly through classification and ordination methods, but taking into consideration M.I.P, they were classified as Community I (*P. densiflora* community), Community II (*Q. mongolica* community), and Community III (*Q. mongolica*-*T. amurensis* community).

2) General Conditions of Investigation Plots

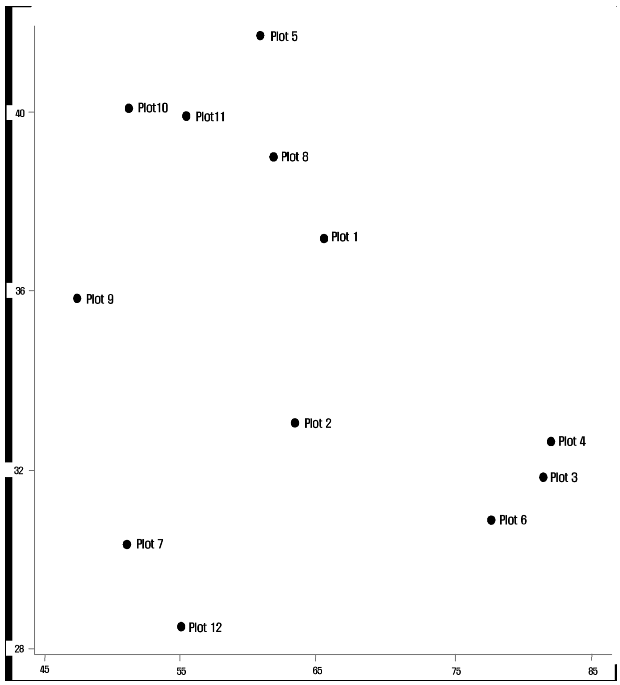

Figure 3. DCA ordination of twelve using plots from the Jilmoi Wetlands through the Donghae Observatory, Baekdudaegan

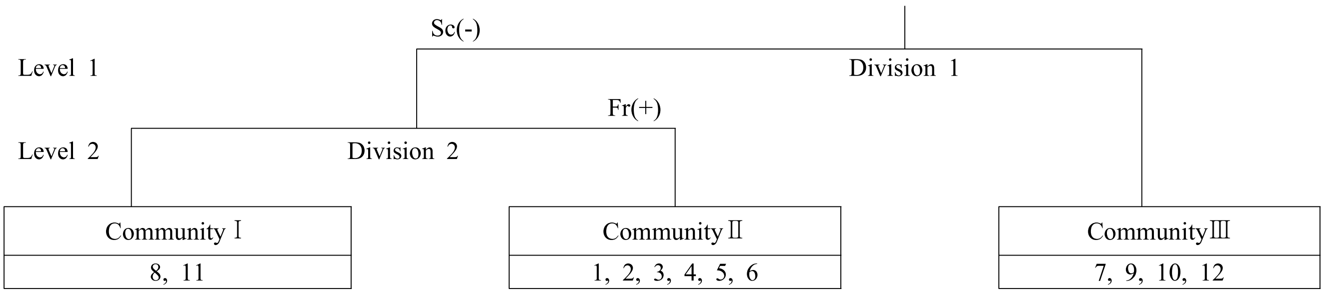

Figure 2. Dendrogram of classification by TWINSPAN using twelve plots from the Jilmoi Wetlands through the Donghae Observatory, Baekdudaegan (*Sc: Sorbus commixta* , *Fr: Fraxinus rhynchophylla*)

Table 1 shows the general conditions per community that were classified using TWINSPAN analysis and M.I.P. Community I is located between 1,079 and 1,099m above sea level with a slope of between 4-16°, and excludes the flat areas, it faces the southeast. For the canopy layer, the average tree height was between 8-12m, the average breadth height diameter was between 22-40 ㎝, and it had coverage of between 65-90 %. For the understory layer, the average tree height was between 4-7m, the average breadth height diameter was between 5-8 ㎝, and coverage was between 10-70 %. For the shrub layer, tree height was under 2.0 m and coverage was between 20-90 %. Community II is distributed between 1,052 and 1,138m above sea level with a slope of between 3-22°, and its main directions are northeast and northwest. For the canopy layer, the average tree height was between 5-9m, with an average breadth height diameter between 10-18 ㎝, and the coverage was between 60-95 %. For the understory layer, average tree height was between 3-6 m, average breadth height diameter was between 4-6 ㎝, and coverage was between 5-60 %. For the shrub layer, the tree height was under 2.0 m and coverage was between 15-40 %. Community III was distributed between 1,090 and 1,167 m above sea level with a slope of between 2-12°, and excluding the flat areas, its main direction was southeast. For the canopy layer, average tree height was between 6-11m, average breadth height diameter was between 10-25cm, and coverage was between 80-90 %. For the understory layer, the average tree height was between 3-6 m, average breadth height diameter was between 4-6 ㎝, and coverage was between 5-10 %. For the shrub layer, tree height was under 0.6 m and coverage was between 40-70 %.

The research target area is the ridge area of Baekdudaegan and is featured by high altitudes and the low tree height of the canopy layer. The canopy layer has mid to large hardwood trees and is in the understory layer, it is covered with smaller trees, thus having an overall multi-layer structure.

3) Importance Percentage

When examining I.P. analysis results by community (Table 2), Community I (*P. densiflora* community) included three investigation plots (3, 4, 6) and in the canopy layer, *P. densiflora* (I.P.: 65.7 %) was dominant along with *Q. mongolica* (I.P.: 15.6 %). In the understory layer, there were *F. rhynchophylla* (I.P.: 34.5 %), *P. densiflora* (I.P.: 20.7 %), *Q. mongolica* (I.P.: 17.9 %), and *S. alnifolia* (I.P.: 8.6 %). In the shrub layer, *S. incisa* (I.P.: 18.7 %) and *R. schlippenbachii* (I.P.: 12.3 %) had high I.P., and *Q. mongolica* (I.P.: 9.1 %), *A. pseudo-sieboldianum* (I.P.: 8.8 %), and *T. regelii* (I.P.: 7.1 %) also appeared. *P. densiflora* was dominant in Community I, in the canopy layer, but in the understory layer, *F. rhynchophylla*, *P. densiflora*, and *Q. mongolica* competed and their succession was judged to be underway. In the

Table 1. General description of the physical features and vegetation of the surveyed plots from the Jilmoi Wetlands to the Donghae Observatory, Baekdudaegan

Community		Ⅰ			Ⅱ						Ⅲ		
Plot		3	4	6	1	2	5	8	11	12	7	9	10
Altitude(m)		1,079	1,099	1,090	1,065	1,065	1,108	1,138	1,052	1,106	1,090	1,167	1,103
Slope(°)		16	4	4	3	3	12	22	3	8	2	3	12
Aspect		S70E	Plain	Plain	N15E	N05E	N20W	N45W	Plain	S10E	Plain	Plain	S10E
Topography		Ridge	Ridge	Ridge	Ridge	Ridge	Ridge	Ridge	Ridge	Ridge	Ridge	Ridge	Ridge
Canopy	Height(m)	8	9	12	6	9	8	8	5	7	11	6	6
	Mean DBH(㎝)	32	22	40	12	16	13	12	10	18	25	10	10
	Coverage(%)	65	85	90	60	80	85	95	80	80	90	90	80
Under-story	Height(m)	4	4	7	4	6	3	4	3	3	6	3	3
	Mean DBH(㎝)	5	5	8	4	6	4	4	4	4	6	4	4
	Coverage(%)	15	10	70	30	15	5	60	40	10	10	10	5
Shrubs	Height(m)	≦2.0	≦1.0	≦2.0	≦2.0	≦1.0	≦2.0	≦2.0	≦2.0	≦1.0	≦1.0	≦2.0	≦1.0
	Coverage(%)	90	20	50	80	20	80	80	80	70	20	70	30
Herbs	Height(m)	≦1.0	≦0.6	≦0.3	≦0.6	≦0.4	≦0.6	≦0.4	≦0.4	≦0.6	≦0.6	≦0.4	≦0.4
	Coverage(%)	20	60	15	15	35	30	20	30	40	70	40	70

Table 2. Mean importance percentage of woody plants by the three classified communities from the Jilmoi Wetlands to the Donghae Observatory, Baekdudaegan

Scientific name	I[1]				II[1]				III[1]			
	C[2]	U[2]	S[2]	M[2]	C[2]	U[2]	S[2]	M[2]	C[2]	U[2]	S[2]	M[2]
Abies nephrolepis	-	-	-	-	0.0	0.6	0.3	0.3	-	-	-	-
Pinus koraiensis	0.9	0.0	0.0	0.5	0.0	0.0	0.3	0.0	-	-	-	-
Pinus densiflora	65.7	20.7	1.0	39.8	11.4	0.0	0.0	5.8	0.0	0.0	0.4	0.1
Salix koreensis	-	-	-	-	-	-	-	-	0.0	0.0	0.4	0.1
Salix hulteni	-	-	-	-	0.0	0.5	0.0	0.2	-	-	-	-
Betula costata	1.1	0.0	0.0	0.6	-	-	-	-	2.6	0.0	3.3	1.9
Carpinus cordata	0.0	0.7	1.7	0.5	0.0	0.5	0.2	0.2	-	-	-	-
Carpinus laxiflora	-	-	-	-	0.3	0.0	0.0	0.2	-	-	-	-
Corylus heterophylla var. *thunbergii*	0.0	0.0	0.6	0.1	-	-	-	-	-	-	-	-
Corylus sieboldiana	0.0	0.0	1.0	0.2	0.0	0.0	2.6	0.4	-	-	-	-
Quercus mongolica	15.6	17.9	9.1	15.2	69.2	32.5	4.0	46.1	63.2	30.5	2.3	42.2
Clematis mandshurica	-	-	-	-	-	-	-	-	0.0	0.0	0.4	0.1
Magnolia sieboldii for. *variegata*	0.0	1.7	3.7	1.2	0.0	0.0	0.8	0.1	-	-	-	-
Lindera obtusiloba	0.0	0.0	0.4	0.1	-	-	-	-	-	-	-	-
Spiraea prunifolia for. *simpliciflora*	-	-	-	-	0.0	0.0	0.1	0.0	-	-	-	-
Spiraea frutschiana Schneid.	0.0	0.0	4.2	0.7	0.0	0.0	3.2	0.5	0.0	0.0	0.5	0.1
Stephanandra incisa	0.0	0.0	18.7	3.1	0.0	0.0	0.8	0.1	0.0	0.0	7.3	1.2
Rubus crataegifolius	0.0	0.0	1.7	0.3	0.0	0.0	8.0	1.3	0.0	0.0	9.5	1.6
Rubus parvifolius	-	-	-	-	0.0	0.0	0.2	0.0	-	-	-	-
Prunus padus	0.0	0.0	0.5	0.1	-	-	-	-	-	-	-	-
Prunus maximowiczii	-	-	-	-	-	-	-	-	0.0	0.0	2.6	0.4
Prunus sargentii	2.5	1.1	0.0	1.7	-	-	0.6	0.1	-	-	-	-
Malus baccata	-	-	-	-	0.3	0.0	0.0	0.1	-	-	-	-
Pyrus ussuriensis	1.2	0.0	0.0	0.6	-	-	-	-	0.7	0.0	0.0	0.3
Sorbus commixta	6.8	6.4	1.8	5.8	2.4	11.4	0.9	5.1	0.0	0.0	0.4	0.1
Sorbus alnifolia var. *macrophylla*	1.8	8.6	5.0	4.5	6.0	8.4	2.8	6.2	2.6	1.2	3.6	2.3
Maackia amurensis	0.8	0.0	0.4	0.5	0.0	0.5	0.1	0.2	0.8	0.0	0.0	0.4
Lespedeza cyrtobotrya	0.0	0.0	0.3	0.1	-	-	-	-	-	-	-	-
Euonymus oxyphyllus	0.0	0.0	0.3	0.1	-	-	-	-	-	-	-	-
Euonymus sachalinensis	0.0	0.7	0.0	0.2	0.0	0.0	0.5	0.1	0.0	0.0	0.5	0.1
Celastrus orbiculatus	0.0	0.0	0.8	0.1	0.0	0.0	1.5	0.3	-	-	-	-
Tripterygium regelii	0.0	0.0	7.1	1.2	0.0	0.0	5.0	0.8	0.0	0.0	5.5	0.9
Acer mono	0.0	0.0	0.7	0.1	0.0	0.6	0.0	0.2	-	-	-	-
Acer tschonoskii var. *rubripes*	0.0	0.0	1.9	0.3	0.0	0.0	1.2	0.2	0.0	0.0	2.2	0.4
Acer barbinerve	-	-	-	-	0.0	0.0	0.4	0.1	-	-	-	-
Acer pseudo-sieboldianum	0.8	4.9	8.8	3.4	0.6	20.2	6.6	8.0	0.0	41.3	6.0	14.7
Tilia amurensis	0.8	2.0	0.0	1.1	3.3	13.2	1.7	6.3	30.0	25.8	4.6	24.3
Actinidia polygama	-	-	-	-	0.0	0.0	0.1	0.0	-	-	-	-
Kalopanax pictus	-	-	-	-	0.4	1.2	0.7	0.7	-	-	-	-
Cornus controversa	0.0	0.7	0.0	0.3	0.3	0.0	0.7	0.3	-	-	-	-
Rhododendron mucronulatum	-	-	-	-	0.0	0.0	2.7	0.5	-	-	-	-
Rhododendron mucronulatum var. *ciliatum*	-	-	-	-	0.0	0.0	5.3	0.9	-	-	-	-
Rhododendron schlippenbachii	0.0	0.0	12.3	2.1	0.0	1.1	26.2	4.8	0.0	1.1	27.4	5.0
Vaccinium koreanum	-	-	-	-	0.0	0.0	0.2	0.0	-	-	-	-
Symplocos chinensis for. *pilosa*	0.0	0.0	6.2	1.0	0.0	0.0	9.0	1.5	0.0	0.0	6.1	1.0
Fraxinu smandshurica	-	-	-	-	1.8	1.3	0.2	1.4	-	-	-	-
Fraxinus rhynchophylla	1.9	34.5	3.6	13.0	3.9	3.1	1.2	3.2	0.0	0.0	1.4	0.2
Syringa reticulata var. *mandshurica*	-	-	-	-	0.0	4.2	0.9	1.6	-	-	-	-

(Table 2. Continued)

Scientific name	Ⅰ[1]				Ⅱ[1]				Ⅲ[1]			
	C[2]	U[2]	S[2]	M[2]	C[2]	U[2]	S[2]	M[2]	C[2]	U[2]	S[2]	M[2]
Syringa wolfi	-	-	-	-	0.0	0.6	0.9	0.4	-	-	-	-
Sambucus sieboldiana var. *miquelii*	-	-	-	-	-	-	-	-	0.0	0.0	0.7	0.1
Viburnum wrightii var. *eglandulosum*	0.0	0.0	2.1	0.4	0.0	0.0	1.2	0.2	0.0	0.0	1.6	0.3
Viburnum erosum	-	-	-	-	0.0	0.0	0.2	0.0	-	-	-	-
Weigela florida	0.0	0.0	6.0	1.0	0.0	0.0	7.6	1.3	0.0	0.0	13.2	2.2
Weigela subsessilis	-	-	-	-	0.0	0.0	0.7	0.1	-	-	-	-
Lonicera maackii	-	-	-	-	0.0	0.0	0.3	0.1	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] Ⅰ: *P. densiflora* community, Ⅱ: *Q. mongolica* community, Ⅲ: *Q. mongolica-T. amurensis* community
[2] C: importance percentage in canopy layer, U: importance percentage in understory layer, S: importance percentage in shrub layer, M: mean importance percentage

shrub layer, *S. incisa* and *R. schlippenbachii* showed relative dominance. Lee *et al.* (2012) reported that the *P. densiflora* community that was distributed in isolation in the upper part of the mountain along the main ridge of Baekdudaegan from Daetje to Baekbongbyeong had a pure *P. densiflora* colony for the canopy layer, but there was competition between *Q. mongolica* and *P. densiflora* in the understory layer, while in the lower level, *Q. mongolica*, *C. cordata*, and *F. rhynchophylla* were dominant, and it was predicted that it would succeed these tree species in the future. In a study on vegetation structures in the ridge area of Baekdudegan between Pijae and Doraegijae, Oh and Park (2002) classified the *Q. mongolica-P. densiflora* community as the typical community of low ridge areas. Also, in a study on the features of *Q. mongolica* in Baekdudaegan according to altitudes between Hyangnobong and Gitdaegibong of Baekdudaegan, Jeong and Oh (2013) said that for the *Q. mongolica* community in areas 900 to 1,100m above sea level, *P. densiflora* grew together with *Q. mongolica* and that in the shrub layer, *R. schlippenbachii* had a rather large community. It is judged that the reason for the decreasing I.P. for *P. densiflora* in the understory layer was compared to the canopy layer because a community mixed with *Q. mongolica* appeared as *P. densiflora* declined with the passage of time at around 1,000m above sea level. In a study on the vegetation structure of Baekdudaegan between Nogodan and Goribong, Kim and Choo (2003) classified the *Q. mongolica-F. rhynchophylla* community, thus there is the possibility for succession to the *Q. mongolica-F. rhynchophylla* community in the future.

Community II (*Q. mongolica* community) included 6 investigation plots (1, 2, 5, 8, 11, 12). In the canopy layer, *Q. mongolica* (I.P.: 69.2 %) was the dominant species, and *P. densiflora* (I.P.: 11.4 %) and *S. alnifolia* (I.P.: 6.0 %) also appeared. In the understory layer, *Q. mongolica* (I.P.: 32.5 %), *A. pseudo-sieboldianum* (I.P.: 20.2 %), *T. amurensis* (I.P.: 13.2 %), and *S. alnifolia* (I.P.: 11.4 %) also appeared. In the shrub layer, *R. schlippenbachii* (I.P.: 26.2 %) had a high dominance value, while *S. chinensis for. pilosa* (I.P.: 9.0 %), *W. florida* (I.P.: 7.6 %), *R. crataegifolius* (I.P.: 8.0 %), and *A. pseudo-sieboldianum* (I.P.: 6.6 %) also appeared. For Community II, in the canopy layer, *Q. mongolica* was dominant and in the understory layer, *Q. mongolica* was dominant, but it was predicted that it would compete with *T. amurensis* to form the next generation. When considering the prediction by Hwang *et al.* (2012) that the *Q. mongolica* community would reduce its proportion through the succsession process and shift to broad-leaved trees such as *F. rhynchophylla*, *T. amurensis*, and *T. mandshurica* through Baekdudaegan natural forests in the Gangwon area community classification and succession trend predictions, there is the possibility to succeed *T. amurensis* and this thus requires continuous monitoring.

Community III (*Q. mongolica-T. amurensis* community) included three investigation plots (7, 9, 10). In the canopy layer, *Q. mongolica* (I.P.: 63.2 %) and *T. amurensis* (I.P.: 30.0%) were the dominant species, and *B. costata* (I.P.: 2.6 %) appeared there as well, In the understory layer, *A. pseudo-sieboldianum* (I.P.: 41.3 %) and *Q. mongolica* (I.P.: 30.5 %) were dominant and competed with

T. amurensis (I.P.: 25.8 %). In the shrub layer, *R. schlippenbachii* (I.P.: 27.4 %), *W. florida* (I.P.: 13.2 %), *R. crataegifolius* (I.P.: 9.5 %), and *T. amurensis* (I.P.: 4.6 %) also appeared. For Community III, in the canopy layer, *Q. mongolica* and *T. amurensis* were dominant, and in the understory layer, *A. pseudo-sieboldianum*, *Q. mongolica*, and *T. amurensis* competed. For the understory, *A. palmatum* showed relative dominance, but competed with *Q. mongolica* and *T. amurensis* in the canopy, and are thus likely to form the next generation. In the shrub layer, *R. schlippenbachii* and *W. florida* displayed relative dominance, and *R. crataegifolius*, *T. amurensis*, and *S.* incisa showed even distribution. Lee *et al.* (2012) reported that in case of the dominant *Q. mongolica* community in the Baekdudaegan Daetjae-Baekbongnyeong section, if there were no competing tree species to replace the lower

Table 3. Distribution of the diameter of the breast height of major woody species in each of the three communities from the Jilmoi Wetlands through the Donghae Observatory, Baekdudaegan

Community	Scientific name	SH	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}
Ⅰ	*Pinus koraiensis*	0	0	0	0	0	1	0	0	0	0	0	0	0
	Pinus densiflora	8	0	0	2	11	8	11	7	10	3	0	2	2
	Betula costata	0	0	0	0	0	0	1	0	0	0	0	0	0
	Quercus mongolica	52	0	6	8	3	5	3	0	1	1	1	0	0
	Pyrus ussuriensis	0	0	0	0	0	0	1	0	0	0	0	0	0
	Sorbus commixta	20	0	1	2	0	1	2	3	0	0	0	0	0
	Sorbus alnifolia var. *macrophylla*	32	0	7	1	1	0	0	0	1	0	0	0	0
	Prunus sargentii	0	0	0	1	1	0	0	0	1	0	0	0	0
	Maackia amurensis	4	0	0	0	1	0	0	0	0	0	0	0	0
	Acer pseudo-sieboldianum	68	0	1	0	3	0	0	0	0	0	0	0	0
	Tilia amurensis	0	0	1	1	1	0	0	0	0	0	0	0	0
	Cornus controversa	0	0	1	0	0	0	0	0	0	0	0	0	0
	Fraxinus rhynchophylla	32	0	19	8	3	2	1	0	0	0	0	0	0
Ⅱ	*Pinus densiflora*	0	0	0	1	3	3	8	1	3	0	0	0	0
	Abies nephrolepis	8	0	1	0	0	0	0	0	0	0	0	0	0
	Carpinus cordata	4	0	1	0	0	0	0	0	0	0	0	0	0
	Carpinus laxiflora	0	0	0	0	1	0	0	0	0	0	0	0	0
	Quercus mongolica	80	0	10	62	66	43	20	4	2	0	0	0	0
	Malus baccata	0	0	0	1	0	0	0	0	0	0	0	0	0
	Sorbus commixta	12	0	11	5	2	2	0	1	0	0	0	0	0
	Sorbus alnifolia var. *macrophylla*	44	0	7	7	8	3	2	0	0	0	0	0	0
	Maackia amurensis	4	0	1	0	0	0	0	0	0	0	0	0	0
	Acer mono	0	0	1	0	0	0	0	0	0	0	0	0	0
	Acer pseudo-sieboldianum	128	0	17	9	3	0	0	0	0	0	0	0	0
	Tilia amurensis	32	0	9	3	3	3	3	0	0	0	0	0	0
	Kalopanax pictus	8	0	2	0	1	0	0	0	0	0	0	0	0
	Cornus controversa	8	0	0	1	0	0	0	0	0	0	0	0	0
	Fraxinus mandshurica	4	0	3	1	1	0	0	0	1	0	0	0	0
	Fraxinus rhynchophylla	24	0	2	4	4	3	1	0	0	0	0	0	0
Ⅲ	*Betula costata*	20	0	1	0	0	0	0	0	0	1	0	0	0
	Quercus mongolica	16	0	7	41	32	15	6	3	1	1	0	1	0
	Pyrus ussuriensis	0	0	0	0	1	0	0	0	0	0	0	0	0
	Sorbus alnifolia var. *macrophylla*	16	0	1	1	0	0	0	0	0	1	0	0	0
	Maackia amurensis	0	0	0	0	0	1	0	0	0	0	0	0	0
	Acer pseudo-sieboldianum	28	0	14	5	2	0	0	0	0	0	0	0	0
	Tilia amurensis	16	0	12	11	10	12	4	1	1	2	0	0	0
	Fraxinus rhynchophylla	12	0	0	0	0	0	0	0	0	0	0	0	0

*$D_1<2$, $2 \leqq D_2<7$, $7 \leqq D_3<12$, $12 \leqq D_4<17$, $17 \leqq D_5<22$, $22 \leqq D_6<27$, $27 \leqq D_7<32$, $32 \leqq D_8<37$, $37 \leqq D_9<42$, $42 \leqq D_{10}<47$, $47 \leqq D_{11}<52$, $D_{12} \geqq 52$

*Plant community names are referred to from table 2 layer, then there would be the possibility to develop into old stands (Cho, 1994; Lee *et al.*, 1996; Choi, 2002), but if competing tree species appearred in the lower level, as shown in Cho and Choi's (2002) research results, it may develop from *P. densiflora* to *Q. mongolica* and then to broad-leaved trees such as *F. rhynchophylla* and *T. amurensis.*

4) Distribution by breast Height Diameter

The method for predicting vegetation succession process through distribution by breast height diameter class was used in past studies (Lee *et al.*, 1990) and distribution results per breast height diameter for each of the three communities are as follows (Table 3). In case of Community I (*P. densiflora* community), *P. densiflora* was evenly distributed with a breast height diameter of between 7-52 ㎝, and there were 17 large trees having a breast height diameter of more than 32 ㎝. *Q. mongolica* showed the majority distribution between a breast height diameter of between 2-27 ㎝, and there were three large trees with a breast height diameter exceeding 32 ㎝. *F. rhynchophylla* also had majority distribution in the breast height diameter of between 2-27 ㎝, and though *P. densiflora* is currently dominant, it does not appear to have a breast height diameter of less than 7 ㎝, and the appearance frequency of *Q. mongolica* and *F. rhynchophylla* is concentrated in small to mid-size trees, so it is judged that in the future, *Q. mongolica* and *F. rhynchophylla* will compete for dominance.

Community II (*Q. mongolica* community) showed an even distribution of *Q. mongolica* with a breast height diameter of between 2-37 ㎝, and the appearance frequency was concentrated in small to mid-size trees with a breast height diameter of between 7-27 ㎝. For canopy, *S. alnifolia*, *T. amurensis*, and *F. rhynchophylla* showed an even distribution in a breast height diameter of between 2-27 ㎝, and in the understory *S. commixta* showed a high appearance frequency at a breast height diameter of between 2-27 ㎝ and an *A. pseudo-sieboldianum* at a breast height diameter of between 2-17 ㎝. *Q. mongolica* had a relatively high appearance frequency in mid-sized trees and it is therefore judged that the *Q. mongolica* community will be maintained for the time being. Also, *S. alnifolia*, *T. amurensis*, and *F. rhynchophylla* had a high appearance frequency in shrubs and it was judged that its dominance in small to mid-size trees will continue to grow.

In Community III (*Q. mongolica-T. amurensis* community), *Q. mongolica* was widely distributed at a breast height diameter of between 2-52 ㎝, and showed a high appearance frequency in a breast height diameter of between 7-22 ㎝. There were three large trees with breast height diameter exceeding 32 ㎝. *T. amurensis* showed high appearance frequency at a breast height diameter of between 7-22 ㎝, and there were also three large trees with breast height diameter exceeding 32 ㎝. In the understory, *A. pseudo-sieboldianum* showed high appearance frequency at breast height diameter of between 2-17 ㎝. Currently, the community is dominated by *Q. mongolica* and *T. amurensis*, and it is judged that *Q. mongolica* and *T. amurensis* will continuously compete for dominance. Choi (2002) stated in the vegetation structure study of the ridge area in the Cheongoksan area of Baekdudaegan that the *Q. mongolica* community is more likely to grow into *Q. mongolica* old stands instead of succession. However, in the understory, in the *Q. mongolica* community where *A. pseudo-sieboldianum* is dominant, it was judged through a breast height diameter class distribution analysis that the number of *T. amurensis* is growing among small to mid-size trees, and therefore, the possibility of succession cannot be excluded.

5) Sample Tree Growth

Upon analyzing the tree age and growth of sample trees per community, Community I's (P. densiflora) *P. densiflora* was from '47 and growth decreased with the passage of time. *Q. mongolica* was from '51, and growth decreased, but annual ring growth remained consistent. In Community II (*Q. mongolica* community), *Q. mongolica* was from '48 and its initial growth was strong, but the annual ring growth continuously decreased, and *P. densiflora* ('51) showed a sharp drop in annual ring growth. *P. densiflora* had a competitive relationship with *Q. mongolica*, and it is therefore presumed that annual ring growth will slow. In the case of Community III (*Q. mongolica-T. amurensis* community), *Q. mongolica* ('91) large caliber trees maintained a slightly slower initial growth, and after 1955, with the growth of *T. amurensis* ('61), it currently has a competing relationship. The growth of Tilia amurensis was stronger than *Q. mongolica*. It was judged that this was in a development stage from *Q. mongolica* to *T. amurensis* (Figure 4). In a vegetation

Pinus densiflora community

Quercus mongolica community

Quercus mongolica-*Tilia amurensis* community

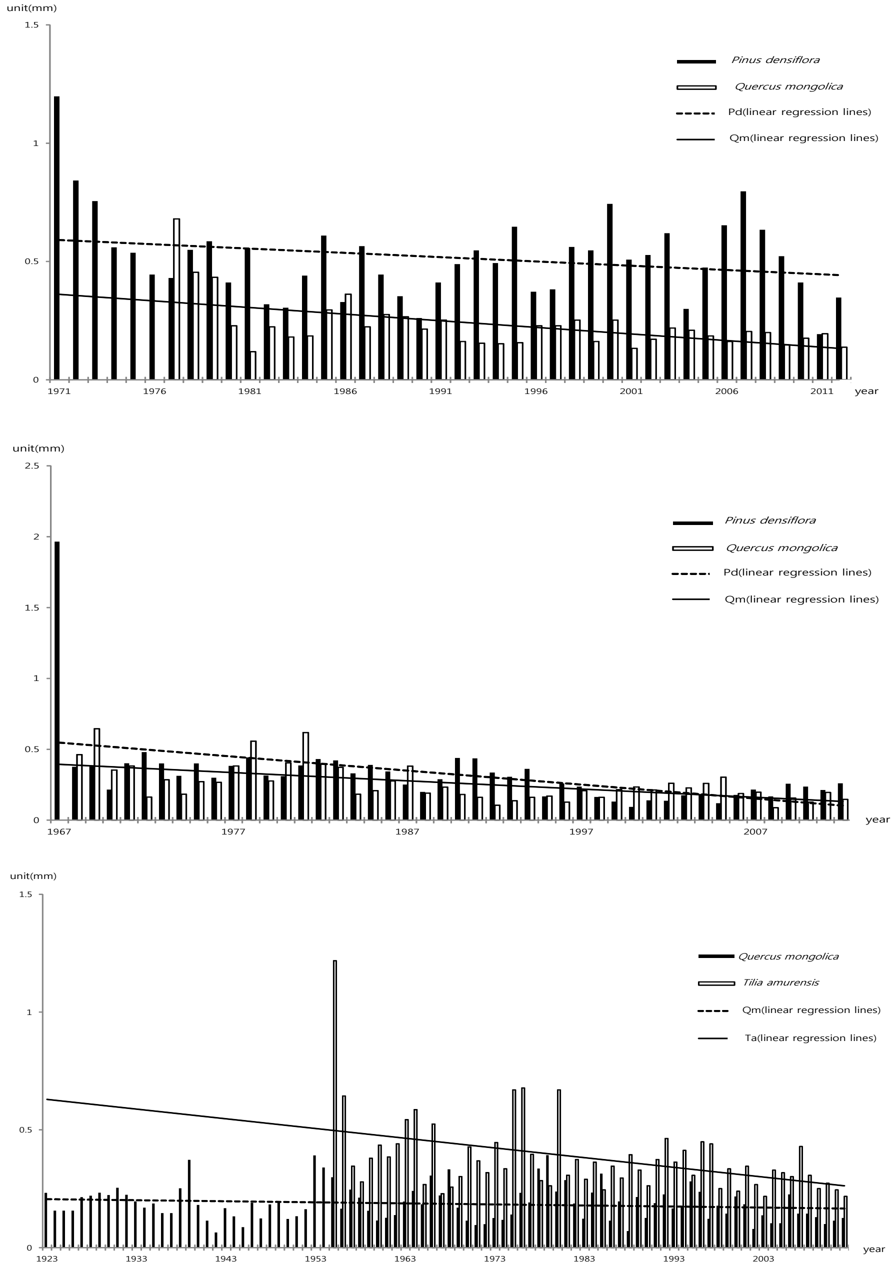

Figure 4. Curve of growth of major woody species of three communities from Jilmoi Wetland to Donghae Observatory, Baekdudaegan

structure study of the ridge area of Cheongoksan in Baekdudaegan, Choi (2002) analyzed the growth of the *Q. mongolica* community and concluded that an age of the 23cm breast height diameter *Q. mongolica*'s was between '33 and the 34.5cm *Q. mongolica* was from '79. Considering the fact that in the research target area, the 23.5cm and 24cm breast height diameters of *Q. mongolica* were '48 and '51, respectively, and the 34.5cm breast height diameter *Q. mongolica* was from '93, it is evident that the growth of *Q. mongolica* in this target area has slowed down.

6) Species Diversity

The species diversity analysis results of the three communities in the Jilmoi Wetlands through the Donghae Observatory in Baekdudaegan are as shown in Table 4. Community I (*P. densiflora* community) showed Shannon species diversity (H') for each 400㎡ investigation plot to have measured between 0.9578 and 1.1862, and it was similar or slightly higher than the Baekdudaegan Baekbongnyeong-Daetjae *P. densiflora* community species diversity of 0.9990 (Lee *et al*, 2012).

The species diversity per the investigation plot of Community II (*Q. mongolica* community) was 0.7904-1.2286, and it was higher than the Baekdudaegan Nogodan-Goribong section *Q. mongolica* community of 0.9274 (Kim and Choo, 2003) and that it was examined at 500㎡ and the Baekbongbyeong-Daetjae section of 0.8046 (Lee *et al.*, 2012), but it was lower than the overall species diversity of the *Q. mongolica* community in Baekdudaegan in the Gangwon region of between 1.884-2.707 (Hwang *et al.*, 2012). Jeong and Oh (2013) analyzed the average max species diversity of the *Q. mongolica* community at between 900-1,100m above the sea level of the Daegwallyeong area to be 0.8620~0.9773 in a study on Baekdudaegan Hyangnobong-Gitdaegibong, and this was lower than the target area of this study's max species diversity of between 1.1761-1.13424.

The species diversity per investigation plot of Community III (*Q. mongolica-T. amurensis* community) was between 0.8701-1.0323, and it was lower than the species diversity of the Baekdudaegan Baekbongnyeon-Daetjae section's *Q. mongolica-T. amurensis* community of 1.1090 (Lee *et al.*, 2012).

2. Physical and Chemical Features of Soil

The soil of the *P. densiflora* community (Ⅰ) was loam and sandy loam with a relatively high content of sand (between 50%-70 %), and had pH of between 5.08-5.11, being slightly higher than the 4.80 of non-cultivated mountain soil (Kim *et al.*, 1993). The O.M. was between 6.58-8.51 %, being lower than the 6.40% of mountain soil, and the Avail. -P was between 0.87-2.59 mg/kg, also lower than the average non-cultivated mountain soil of 5.60 mg/kg. Cation content was considerably lower in Ca^{2+} and Mg^{2+} contents compared to non-cultivated mountain soil. The *Q. mongolica* community (Ⅱ) had sandy loam with relatively high sand content and a pH of between 4.78-5.21, being slightly higher than 4.80 of non-cultivated mountain soil. O.M. was between 7.32-10.55 %, slightly higher than the 6.40 % of mountain soil and both Avail. -P (between 0.88-4.15 mg/kg) and cation (Ca^{2+}, Mg^{2+}, K^{+}) content was also considerably lower compared to non-cultivated mountain soil. *Q. mongolica-T. amurensis* community (Ⅲ) also included sandy loam with relatively high sand content (between 70 %-90 %). Hydrogen ion concentration (pH) was between 4.72-5.03, displaying acidified values compared to a pH 4.80 of non-cultivated mountain soil. O.M. (between 7.49-8.34 %) was higher than average non-cultivated mountain soil, while both Avail. -P (between 1.66-2.29 mg/kg) and cation content (K^{+}, Ca^{2+}, Mg^{2+}) being lower than non-cultivated mountain soil (Table 5).

Table 4.The species diversity of three communities from the Jilmoi Wetlands to the Donghae Observatory, Baekdudaegan (Unit area: 400㎡)

Community	Plot	H'(Shannon)	J'(evenness)	D(dominance)	H'max
Pinus densiflora community	3	1.1816	0.8802	0.1198	1.3424
	4	0.9578	0.7954	0.2046	1.2041
	6	1.1862	0.8485	0.1515	1.3979
Quercus mongolica community	1	1.1240	0.8501	0.1499	1.3222
	2	1.1222	0.8625	0.1375	1.3010
	5	0.9743	0.7762	0.2238	1.2553
	8	1.1331	0.8441	0.1559	1.3424
	11	1.2286	0.8490	0.1510	1.4472
	12	0.7904	0.6721	0.3279	1.1761
Quercus mongolica-Tilia amurensis community	7	1.0323	0.8073	0.1927	1.2788
	9	0.8701	0.8355	0.1645	1.0414
	10	0.9755	0.8294	0.1706	1.1761

Table 5.The soil property of three communities from Jilmoi Wetland to Donghae Observatory, Baekdudaegan (Unit area: 400㎡)

Community	Plot	pHw	EC1:5	O.M.	Avail.-P	Ca	Mg	K	Na	Soil texture	CEC
		1:5	dS/m	%	mg/kg	───cmol/kg───				-	cmol/kg
Pinus densiflora community	3	5.08	0.02	8.51	2.59	0.15	0.10	0.21	0.09	Sandy loam	18.27
	6	5.11	0.02	6.58	0.87	0.04	0.07	0.39	0.09	Loam	21.80
Quercus mongolica community	1	4.92	0.04	7.32	4.15	0.12	0.08	0.11	0.10	Sandy loam	21.17
	5	5.21	0.02	8.34	0.88	0.07	0.10	0.14	0.18	Sandy clay loam	22.11
	8	4.78	0.02	10.55	0.96	0.13	0.12	0.22	0.11	Sandy loam	45.79
	12	4.78	0.03	9.19	3.10	0.04	0.07	0.21	0.13	Sandy loam	19.99
Quercus mongolica-Tilia amurensis community	9	5.03	0.03	7.49	2.29	0.21	0.18	0.21	0.11	Sandy loam	20.46
	10	4.72	0.04	8.34	1.66	0.07	0.09	0.15	0.15	Sandy loam	23.28
means		4.95	0.03	8.29	2.06	0.11	0.10	0.21	0.12	-	24.11
Uncultivated Forest Soil		4.80	-	6.40	5.60	2.27	0.70	0.25	-	-	-

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